Joint Distributed Engineering Plant Technical Framework:
Applying Industry Standards to System-of-System Federations for Interoperability

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Abstract: *The Joint Distributed Engineering Plant (JDEP) is a DOD- and Service-funded initiative created to support interoperability. JDEP facilitates access, coordination, scheduling, and technical support to replicated joint operational environments through the reuse of simulation and hardware- and software–in-the-loop (HW/SWIL) capabilities across the DOD and industry. This allows for the creation of distributed federations for use in the development, integration, testing, and assessments of systems and systems of systems. Although this is not a new concept, conducting events on a joint level to synchronize efforts, resources, and assets across the services by critical mission areas is a new approach. The JDEP technical framework comprises the components of a JDEP configuration, interfaces, and guidance on how to configure and apply the components to meet user needs. This technical framework is critical to cost effectively federating simulation and HWIL systems across multiple communities.. Because industry is a key player, the JDEP technical framework is based on industry standards, including the HLA, and is being implemented using standards-based commercial products wherever possible. This paper describes the framework, the migration strategy and progress to date in assessing and applying the technical framework.*

Introduction

System interoperability has become a priority in the US DOD. The US war fighting doctrine increasingly calls for more effective joint and coalition operations (JV 2010 and 2020) requiring cooperative action by multiple systems. Consequently, there is a growing need to ensure that the systems in the field today and the new systems in development are designed to work as part of a larger system of systems (SoS). These SoS need to be integrated and tested routinely during development and especially prior to deployment, as well as each time new systems are added to the larger SoS or existing systems are modified. Recognition of the importance of interoperability is seen in the creation of the Single Integrated Air Picture (SIAP) Systems Engineering (SE) Task Force FY00, the overarching Family of Interoperable Operational Pictures (FIOP) in FY01, and most recently the Single Integrated Ground Picture (SIGP) in FY02.

The Joint Distributed Engineering Plant (JDEP) is a funded initiative created to support the interoperability needs of developers, testers, and warfighters as well as the ‘cross-program’ initiatives (e.g. SIAP). (Ref) JDEP provides users with the ability to identify and access existing HW/SWIL and simulation capabilities across the DOD and industry, and technical support to federate them into distributed system environments for use in development, integration, testing, and assessments.

JDEP “events” occur each time that a set of capabilities is configured and used to meet specific users needs. These events include the full process of planning, configuring and executing a federation, as well as the collection and analysis of data from the federation. JDEP events are expected to be numerous routine activities that may be small (two or three system) configurations to address the specific needs of a developer, tester or war fighter, perhaps in conjunction (following or preceding) with larger events. User needs will drive when events take place, and which capabilities will participate.

The JDEP technical framework defines the components which may comprise a JDEP federation, interfaces (specifications) for the way the components work together, and guidance on how to configure and apply the components to a users needs. It is the general ‘blueprint’ for assembly of the ’piece parts’ to address a particular issue. This framework has been designed to consider the broader purposes of JDEP, applying existing standards and tools wherever possible.

This paper describes the technical framework, the migration strategy and progress to date in assessing and applying the framework.

Why a JDEP Technical Framework?

To achieve JDEP goal of enabling users to address SoS issues throughout the life cycle a technical framework is needed which supports cost effective reuse of available components in configurations that met individual users needs.

Currently, there are many different technical approaches to linking HWIL and simulation environments. JDEP is based on the premise that different these HWIL, and simulation environments, as well as range-based systems can be readily intermixed, along with representation of salient features of the operational environment, to create federation events to meet different user needs. To make this a cost-effective reality, a technical approach to bridging the current approaches into a common framework for JDEP federations is needed.

Different organizations, systems, companies, have developed ‘environments’ to link HWIL and simulations to meet their needs. Each have their own infrastructure, characteristics, processes, and integrators. Unless JDEP creates a common/openinfrastructure, each time JDEP supports a different user a new development will be required to ‘upgrade the HWIL’ for the ‘host environment’. JDEP resources will be devoted to multiple system interface upgrades for the same system to operate in different ‘environments’. Alternatively, JDEP resources could be devoted to building system interfaces to a common infrastructure which can be reused by multiple different users and ‘gatewayed’ into existing infrastructures when appropriate.

JDEP has already encountered this issue. In FY01 a proof of concept event was conducted for SIAP SE using the Navy Distributed Engineering Plant (NDEP). For this event, the Boeing AWACs HWIL was upgraded for integration into NDEP and connected to their ATM network according to NDEP specifications. In FY02, the Missile Defense System Exerciser (MDSE) was nominated for use for SIAP SE event (although it was not selected for use).

Neither the network connectivity and nor the interface SW met the prerequisites for integration of the Boeing AWACS or any NDEP node into MDSE. Consequently, future use of Boeing AWACs in other environments (e.g. AF CEIF) will require added development and integration. In addition, because MDSE is an environment owned and developed by a particular organization for its own needs, the needs of owner take priority for MDSE integration and event resources.

Consequently, the proposed approach for JDEP is to create a common technical framework as basis for JDEP investments. Upgraded systems and new systems interfaces will be implemented using the technical framework. Owners of current infrastructures can reuse these upgrades or new systems through gateways or other CM based 'interface switches'. JDEP events will be based on federations using the technical framework. To ensure general acceptance and broad utility, the JDEP technical framework will be based on open industry standards and standards-based commercial software and tools.

Framework Objectives

The need for a technical framework to support JDEP was recognized as part of the JDEP Strategy:

> In order to assist in the reuse process, a blueprint is needed which provides the framework for the reuse of available capabilities. As a technical framework for composition of JDEP capabilities into federations, this framework will provide a lay down of the different **types of components** which compose a JDEP federation, the **interfaces** among those components, and **general guidance** on how different components work together to form a federation. No such specific framework exists, but there is a lot of experience as well as existing and new architectures and interface standards which will be used to create this framework. In JDEP, it will be important to balance the desire for structure and standards that will aid in ease of composition and reconfigurability with flexibility needed to accommodate both the variety of user needs and the state of current, legacy components. (Ref: JDEP Strategy Final Report)

Early planning discussions of the JDEP technical framework (Ref: JETF report) mirrored the NDEP architecture as it was in place at that time. The report envisioned a dedicated network with continuous links to a suite of sites used for one specific user application. The NDEP's configuration and supporting tools were sufficient in scope and purpose for the FY01 proof-of-principle event considering the cost and time required. This event offered valuable lessons learned for JDEP processes and technical approach. In FY02 the MDSE was also proposed as the basis for the JDEP. As with NDEP, MDSE was designed with a particular set of applications in mind, and while it serves its current users well, it was assessed to lack the breadth, accessibility, flexibility or extensibility to support the broad set of applications and users envisioned for JDEP over the long run.

Based on the JDEP Strategy:

> To be of use to JDEP, this technical framework needs to provide the blueprint for reuse and reconfiguration of available components into federations to support new SoS applications. It has to be able to accommodate the different types of components which will be incorporated into these configurations, and it needs to support geographically distributed

federations and federations with varying numbers of nodes and volume of traffic. Finally, the framework needs to be practical, because its primary function, at least in the near term, is the configuration of legacy capabilities, and, if possible, it would be advantageous to avoid the need for a large investment to upgrade these to get extended use of JDEP underway. (Ref: JDEP Strategy Final Report)

Framework Considerations

The broad of scope for JDEP both in terms of mission areas and users requires an encompassing view of the needed technical framework. This includes the full range of the types of federates to be included in JDEP federations, particularly simulations. It requires flexibility in the types of data to be collected and the types of analyses to be conducted. Rather than a single dedicated continuous federation, JDEP federations will come and go as needs arise and change. Current network connectivity among sites needs to be employed whenever possible, rather than necessarily implementing a new network capability for JDEP events. The framework must support concurrent events to be conducted, with multiple federations operating independently to support multiple, different user needs, so JDEP can respond to the growing need for interoperability events across mission areas.

The major drivers, then, to the technical framework include the need to:

- Support multiple mission areas, with systems/assets reused across mission areas
- Support creation of federations to meet user needs, rather than maintain standing federations for specific areas

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To meet this range of needs, JDEP is basically conceived not as a 'system' or 'standing 'plant' or facility. Rather, as a set of distributed components that can be configured into federations based on a set of basic technical open industry standards tailored to address the needs of a particular user.

Role of Simulation

JDEP has been fundamentally viewed as a HW/SWIL SoS capability, however, it is important to recognize the integral role of simulation. Even in a 'pure' HWIL application, simulation is used in the "sim stim" and communication interfaces to the HWIL components.

A HWIL system's "sim-stim" capability typically models the physical platform (movement position), the sensor collector capabilities, and the physical characteristics of the weapon system). It injects this data into the 'processor' components of the system, along with other external data about the environment that would affect the system. What a 'sim-stim'component includes, and to what degree of detail (I.e. fidelity), is driven by the needs of the application. The "comm" interface typically replaces the communication hardware (e.g. radio) with an interface to a surrogate communications method (e.g.) the network to emulate the communications among the distributed networked systems.

In a lab based, HW/SWIL environment, you are essentially providing a set of drivers to a system to create the effect of the system operating in a more realistic physical environment. Because the systems are typically stationary in distributed laboratories, the HWIL systems are augmented by elements ('compensating' components in key areas such as platform physical behavior and communications exchanges) to reflect their behavior in a more realistic physical environment. This 'compensation' is done in the 'sim-stim' and 'comm interface' components. Depending on the nature of the use of the HWIL capability, these components replace elements of physical system (radar receiver, radios, platform movement, etc.) with the appropriate simulations of these system attributes, while exercising the actual hardware and software. The decision as to what to represent in the sim-stim or comm interface, and the degree of detail to represent, depends on the nature of the use.

Beyond this, simulation is a necessary prerequisite for immersing the HWIL into increasingly realistic operational environments. Blue systems can be represented in simulations, allowing for use of these simulated representations in lieu of HWIL when appropriate. This could be useful in replacing high demand systems needed in multiple applications. It can also be useful in the early stages of development, before prototyping, when only simulated representations are available and SoS issues need to be addressed. Simulations have advantages in terms of flexibility and portability, and cost of instrumentation and reproduction (creating added copies). However, since these are 'representations' and not the 'real thing', the validity of the representation and its appropriateness to the application must be addressed whenever simulations.

The Framework

Based on results of the JDEP Strategy study, experience in the first year JDEP proof of principle event, and a review of ongoing activities across the department and in industry, a draft framework was developed in FY02. It is shown in the figure below.

Working upward, the layers in the framework are described along with the current approach to supporting the services in JDEP.

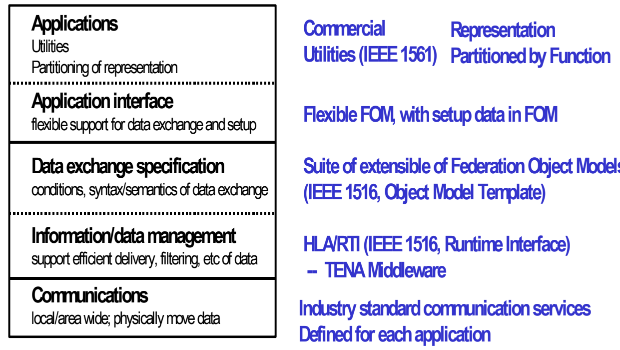

Figure 1: JDEP Technical Framework

- **Communications**: JDEP federations will employ industry standard communications services, which will be defined for each application. These services will support local and wide area data transport. The types of federations that JDEP will support are varied in the amount of data that needs exchanged, the exchange constraints, and how potential JDEP sites are already equipped with communications network capabilities. As a result, JDEP will address the specific needs and resources available to each federation in defining communication support.

- **Information and Data Management**: JDEP information and data management will be based on IEEE 1516 (HLA) runtime interface services via a compliant runtime infrastructure. These services will provide efficient data delivery and filtering of data. HLA 1.3 is the DOD standard for simulation interoperability and it has been demonstrated to be applicable to support live system interfaces (REF: JADS), HLA has been selected as the standard for JDEP, beginning with 1.3 and moving to 1516 as the products become available. Many current HWIL federations use DIS. But because of the broader JDEP mission to support development of new systems (prototypes), test existing systems, provide enhanced operation realism (environment and electromagnetic effects), and support larger scale, man-in-the loop dynamic environments, HLA was selected for JDEP due to its added capabilities for extensibility and flexibility. Upgrades or gateways to DIS systems are envisioned. The Test and Training Range Enabling Architecture (TENA) middleware will be used to support exchange of data with range systems, which as it matures and is deployed across the DOD will ease the cost and complexity of adding range-based systems to JDEP federations.

- **Date Exchange Specifications:** JDEP exchange will be based on the IEEE 1516 (HLA) Object Model Template specification for defining the conditions, syntax and semantics of data exchanges. JDEP expects to maintain a suite of reference federation object models (FOMs) which will be used to derive the FOMs for particular federations, easing the cost and time in for each new federation.

- **Application Interface**: Interfaces between applications and the RTI will be built for flexibility, including what has been termed 'FOM agility.' This is the ability to adapt the interface to reconfigure the FOM for a particular federation, selecting a subset of information and adjusting the class hierarchy to address the needs of the particular federation. This will allow federates to support multiple federations with different mixes of federates without software changes. In addition, also for generality and flexibility, remote setup will be supported through the interface.

- **Applications:** The lower layers will support applications or federates of two types. First, federation utilities operate through the same interface as other federates (simulations, HWIL). In JDEP commercial utilities will be employed to the extent possible. Second, are the representations of systems, environment, communications etc. which form the environment and event contents. As shown in the figure below, representations (to include HW/SWIL, simulated, or live) are partitioned into basic components to allow for ease of adapting to specific needs of the federation (whether, which type and which instance), and to ensure common representation across federation as needed.

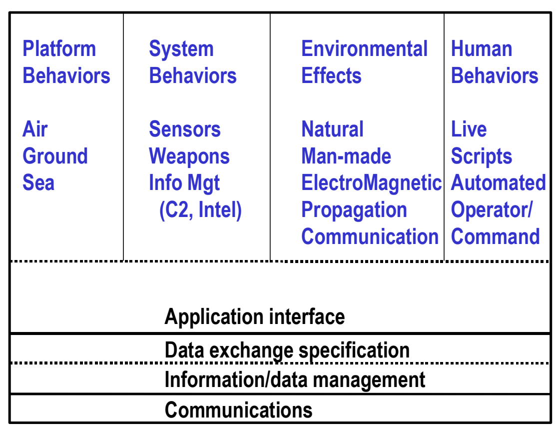

Figure 2: Functional Representation

Advantages of A Standards-Based Approach

DOD promotes use of industry standards, and use of a standards based approach to a component based framework like that presented for JDEP.. Available commercial products make federation development faster, cheaper, and easier to upgrade. By separating systems and other representations from the infrastructure, potential to easily 'upgrade' or substitute different renditions (e.g. better sensor model). Because interfaces are based on industry standards, it is possible for multiple developers to work concurrently and for components developed for one application to be more readily reused in another. Using industry standards means some of the components may already be compliant. In JDEP's case, this is particularly true for simulations and support utilities. Finally, the components can be reused in many different federations, with different managers and users, with the same federate participating in multiple different federations.

It should be recognized however, that a 'standards-based framework', whatever the advantages, is still only a framework. It is still necessary to clearly define the problem, select/develop the right federates with the right characteristics, and verify, validate and accredit the federation for the problem. It is still necessary to develop and maintain the federates (simulated and HWIL) with the fidelity and characteristics needed for the problem being addressed, although these should be more readily reusable if implemented using recognized standards. There is no guarantee that federates developed to address one problem will be appropriate to address another problem, but those that are appropriate can be more readily accessed and reused.

JDEP Support to Application of the Framework

JDEP will support federating of capabilities based on a common infrastructure. JDEP will support the development of federations using the technical framework by promulgating selected commercially developed products, which can ease integration and operation of federations. As shown in the figure below, gateways to existing infrastructures can be 'productized' and managed as JDEP assets. New systems can be added to the core with supported by commercial interfaces libraries. Commercial utilities (data collectors, viewers, management tools) can be used with federations with different mixes of components. Interfaces to ranges will be supported via standard gateways to Test and Training Enabling Architecture (TENA).

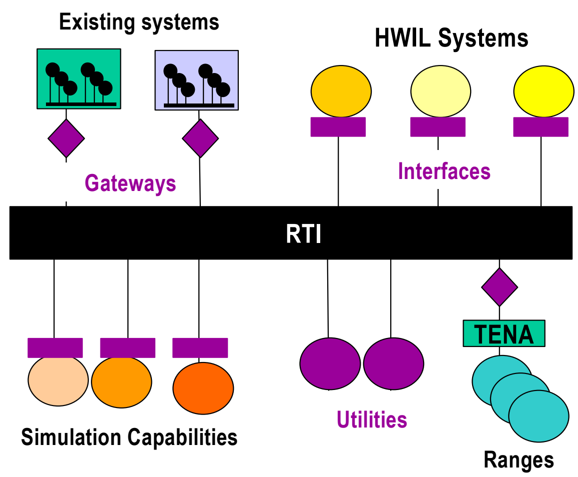

Figure 3: Depiction of a JDEP Federation

- **Gateways**

JDEP will support development of a 'set' of gateways, in partnership with current federation owners and managers. This will allow a structured approach to common gateway functions based on commercial products, incorporating functionality common to JDEP Interface, incorporation/updating of management functions across set of JDEP supported gateways, as well as reducing risks and lowers cost (vice ad hoc approach). This functionality will be built in cooperation with existing infrastructure owners/ developers.

- **Interfaces**

Interface libraries, will be part of JDEP core infrastructure to support lower cost incorporation of new systems. These will be based on commercial products, and will incorporate ability to adapt the federation data exchanges, setup starting situations automatically. These will be integrated into systems in partnership with the system owners and developers and will incorporate the ability insert federation data into system representation including necessary interfaces to the tactical drivers for HWIL.

- **Utilities**

Utilities are comprised of a set of basic support tools that can be reused in federations of different mixes. These will be based on commercial products or adaptations of current capabilities and will include federation management tools, data collection tools, monitors and viewers.

Implementation Approach and Progress

JDEP completed its first startup year of operations in FY01, with the development of the JDEP Strategy to guide JDEP evolution and management and with the conduct of a proof of principle event in the NDEP which offered both technical and process lessons learned for the initiative. In FY02, a new management approach was established which separated the support for common infrastructure from applications. This technical framework which lays out an application independent technical way ahead is a product of this new structure. It was drafted in the first quarter of FY02, presented and discussed with the major JDEP customers during the second quarter, and it has been applied to the development of plans for JDEP FY02 events.

The major FY02 user applications of JDEP are in the Air and Missile Defense arena. The Single Integrated Air Picture Systems Engineer (SIAP SE) was the customer of the FY01 proof of principle event and is the highest priority JTAMD customer of JDEP in FY02. After the SIAP SE assessed current infrastructures and found them unable to meet their SE needs, work began to apply the framework to create a persistent federation which could be used to address the set of SIAP critical experiments which have been developed to support the SIAP block upgrade process. A set of pilot federations will be developed and executed to address near term issues and to serve as the building blocks for the capability to address issues in subsequent years. JDEP is also supporting the Air Force Electronic Systems Command (ESC) in their Korean TADIL Improvement Program (KTAIP) by supporting a federation based on the framework to assess the a correlation capability. In addition, a pilot implementation of the framework has been initiated in a Joint Time Sensitive Targeting (TST) test bed which links three Service laboratories to address joint time sensitive targeting issues in a joint HWIL and simulation environment. This technical pilot will support the assessment of commercial product and implementation issues in the transition to use of the JDEP framework.

Based on the results of these three efforts, the JDEP Framework will be, to provide an evolving technical base for development and execution of federations of HWIL and simulations to support developers, testers and war fighters to create environments to address interoperability of systems of systems.

References

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Author Biographies

Dr. Judith Dahmann is a principal senior scientist at the MITRE Corporation and the Scientific Advisor to Dr. Garber, Director of Interoperability for the US Under Secretary of Defense for Acquisition, Technology and Logistics. In this capacity, Dr. Dahmann provides technical review, assessment and recommendations on interoperability plans, issues and initiatives, including the application of emerging commercial technologies throughout the system acquisition cycle. Dr. Dahmann is also participating in the technical development of a DOD enterprise infrastructure initiative to support creation of distributed system of system federations with simulation, hardware-in-the-loop and live systems to support integration and test throughout the life cycle. Prior to this, Dr. Dahmann was the Chief Scientist for the Defense Modeling and Simulation Office for the US Director of Defense Research and Engineering, a position she held from 1995 to April 2000. In her role as Chief Scientist, Dr. Dahmann led the development of the High Level Architecture, a general-purpose software architecture for the development and interoperation of simulations, now an IEEE Standard (IEEE 1516).

Richard Clarke is the technical director for the Joint Distributed Engineering Plant. (JDEP). Clarke graduated from the University of Arizona in 1987, receiving a bachelor of science in systems engineering. He worked for the U.S. Army as a contractor developing and then managing development of instrumentation packages for large scale developmental testing and operational testing programs. In 1993 he joined the Joint Interoperability Test Command and worked interoperability certification with a focus on air and missile defense. In 2000 he assumed position of air and missile defense systems branch chief. In 2001 he assumed his current position as testbed engineering branch chief and technical director for the JDEP.